UNIVERSITY OF DELAWARE
CENTER FOR COMPOSITE MATERIALS
INTERNATIONALLY RECOGNIZED EXCELLENCE

MULTIFUNCTIONAL MATERIALS AND STRUCTURES

S. Yarlagadda

UD-CCM

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Enabling Transformation of the Navy

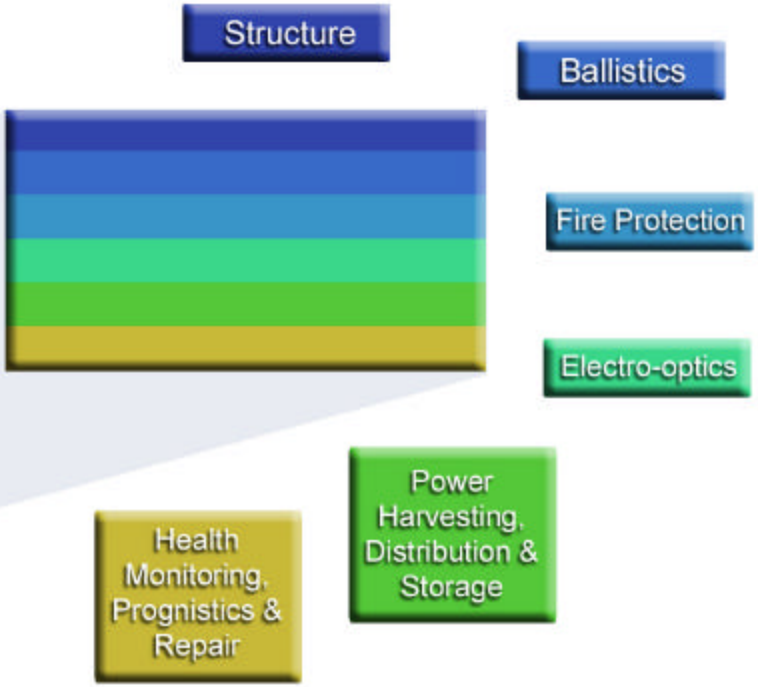
- **Relevant Surface Platform requirements:**
  - Autonomous Operation, Crew Reduction
  - Lightweight, High Performance Systems
  - Signature Reduction
  - Integrated Electric Power
  - Affordability
- **Proposed Solution – "LIVE" Ship Concept**
  - Lightweight, High Performance Multifunctional Composite Structure
  - Desired Functionalities: Structure, Blast, Ballistic, Fire, Network/Communications, Signature, Power, Health Monitoring, Prognostics and Repair
- **Challenge**
  - Develop Materials and Process Technologies that enable Modular Plug-and-Play Functionality in Composite Structure

Navy After Next Surface Platforms

References

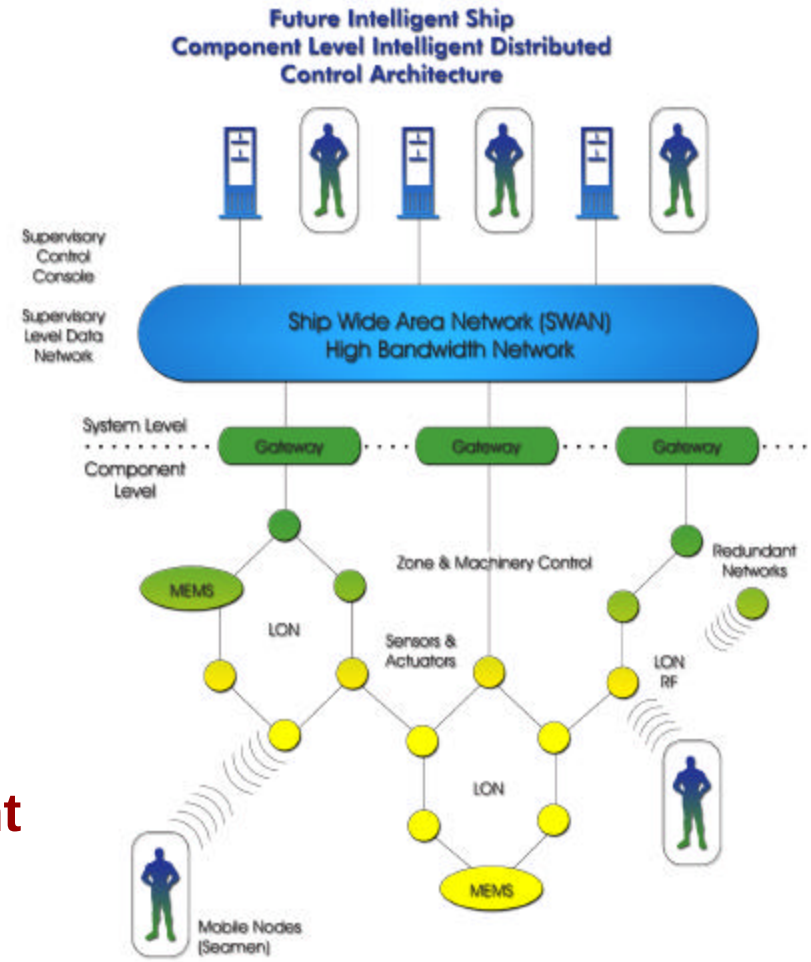
- **Technology for the United Stated Navy and Marine Corps, 2000-2035: Becoming a 21st-Century Force**
  - National Research Council Report initiated by the CNO (1997)
  - 9 Volume Study, Volume 6: Surface Platforms
- **Future Naval Capabilities (FNC)**
  - http://www.onr.navy.mil/fncs/
- **Department of Navy: Science and Technology Grand Challenges**
  - http://www.onr.navy.mil/sci_tech/grandc.htm
- **Navy DD(X) Program**

“LIVE” Ship Concept



Example: Ship Area Network (SAN)

- **"LIVE" Structure**
  - Self-Contained Network
  - Communications, Signature, Health Monitoring, Damage Assessment
  - Devices within Structure - Nodes
  - Integration with WPAN
- **Advantages**
  - Redundant, Reconfigurable
  - Automation Capable
  - Rapid Response
  - Active Signature Management
  - Fault Tolerant, Graceful Degradation



“LIVE” Ship Concept

- **Meets Navy After Next Requirements**
  - Next Generation Solutions for Structure, Blast, Fire and Ballistics
  - Integrated Ship Area Network (SAN) and Autonomous Operation
  - Reduced Crew, Flexible Architecture
  - Active Signature Management
  - Local Electric Power Harvesting for Self-Sufficient Systems
  - Self-Diagnostics, Prognostics and Repair Capability
  - Affordability
- **Builds on many Individual Technologies being developed by DoD/Industry**
  - System Integration and Manufacturing is the Grand Challenge
  - Technology Development, Manufacturing Methods and System Integration must occur simultaneously
- **Similar concepts being evaluated for other Applications (Soldier Systems)**
  - Advantage for Ship Structures: Large Size and Large Surface Area!
  - Allows integration of relatively larger systems/devices etc

Enabling Technologies

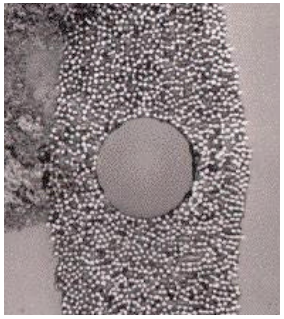
- Technologies for Multifunctional Composite Structures
  - Electro-Optics – Communications and Signature
  - Materials
  - Simulation tools
  - 3-D Functionally Gradient Structures
  - Cradle-to-Grave Sensors and Actuators
  - Small-scale Devices (micro- to nano-)
- Manufacturing and Systems Integration
  - Electronic Preforms
  - Integration of enabling technologies into preforms/manufacturing

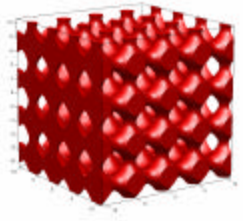
Manufacturing Considerations

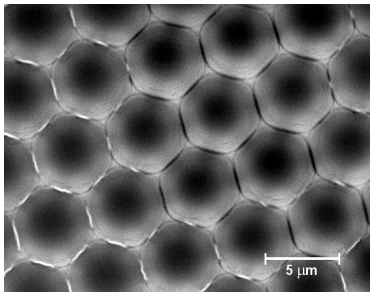
- **Manufacturing and Systems Integration Considerations**
  - **Functionality insertion through multi-scale**
    - Fibers – Electronic Preforms
    - Resins – Multi-resin Structures (Co-Injection)
    - Fillers – Multiple fillers (micro- to nano-)
  - **Constraint of Liquid Molding (VARTM/RTM) as primary manufacturing process**
    - Inserted Technologies must survive process
  - **Compliment current structural, fire, blast and ballistic capabilities**
  - **Systems Design approach rather than design for individual requirements**
  - **Affordability**
  - **Long-term durability**

Electro-Optics

- **Next Generation**
  - 2-D and 3-D Photonic Crystals
  - Graded Dielectrics
  - Frequency Selective Surfaces
  - Nanostructured Systems (aerogels, foams)
  - Conductive Polymers
  - Left-Handed Materials
- **Integration into Composite**
  - Micro- to Nano-particulate systems
  - Tailored Porous media
  - Manufacturing strategies for desired composite microstructure





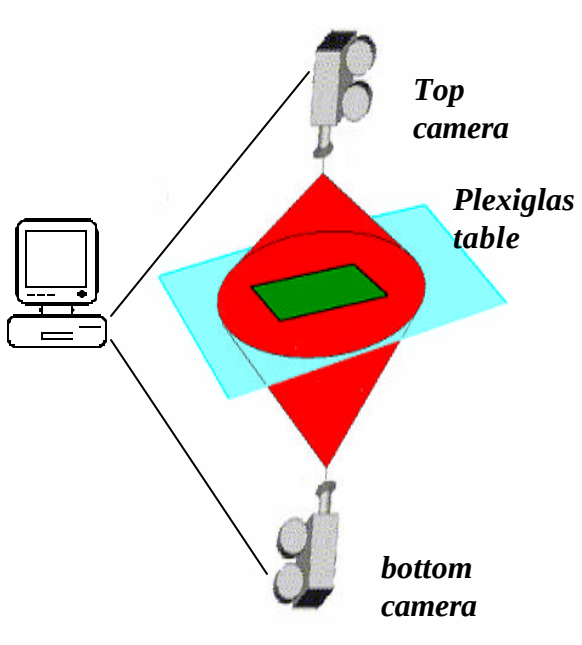


Example: Photonics and Metal-less Masts

- Photonic Crystals, Graded Dielectrics and Nanostructured Materials
  - Next generation building block material
  - Unique Tunable properties in EM spectrum
  - Networking, Communications and Signature
- LO “Metal-less” Mast using Conductive Polymers
  - Fluidic Antenna Concept
  - Mast structure consists of Channels/Gates Grid
  - Conductive Liquid Polymer based
  - Control Gates for Reconfigurable Geometry Antennas etc
  - Remove Polymer when not in use (LO)

3-D Functionally Gradient Structures

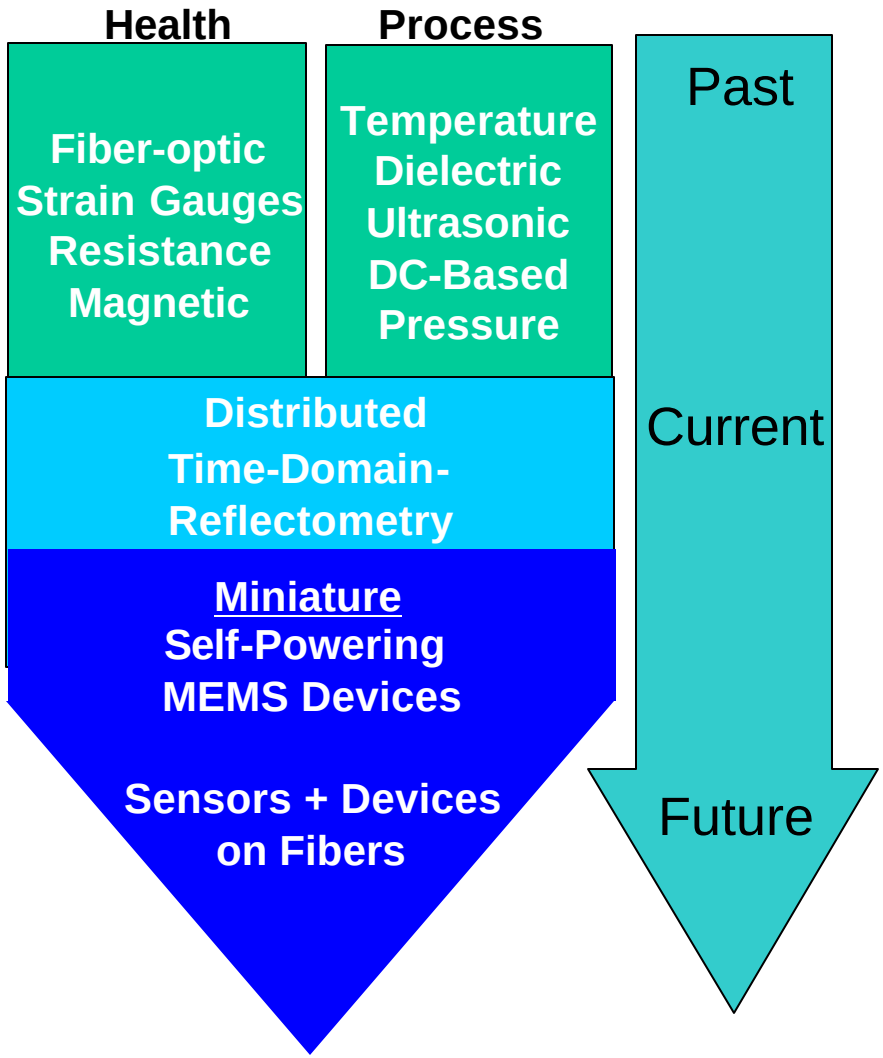
- **Evaluate property-processing relationship for**
  - **Graded fibers, resins and fillers**
  - **Selection based on desired functionality**
  - **Develop design and processing guidelines**
- **Example: Particulate fillers**
  - **Micro- to Nano-scale**
    - Carbon black to nanotubes
    - Dielectrics
    - Magnetic
  - **Particle size – preform permeability – resin viscosity relationship**
  - **Tailor particle composition, size, preform and resin for desired graded functionality**



Cradle-to-Grave Multifunctional Sensors

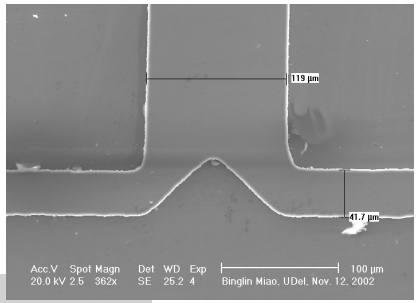
- Multi-Functional Sensor Technology Requirements
  - Monitors Manufacturing Process
    - Measures several quality and process parameters
  - Embedded sensor monitors Structural Health
  - Distributed
  - Wireless
  - Self-Powered
  - Miniature Implementation

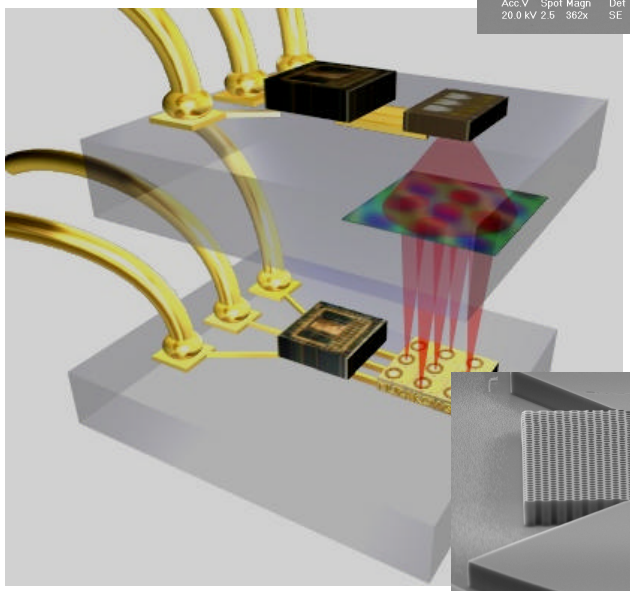
- Transparent to Material
- Enables Process Control
- Enables QA/QC
- No Ingress/Egress Issues

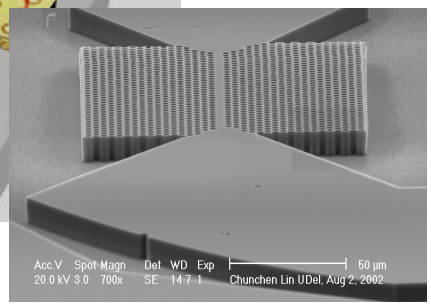


Small-Scale Active Devices

- Need Devices for
  - Networking – Encoders, Decoders, WDM etc
  - Sensors/Actuators
  - Energy harvesting
- MEMS and NEMS Technology
  - Passive devices
  - Active devices with CPU
  - Field Programmable
  - Device on fiber
- Integrated into Electronic Preforms

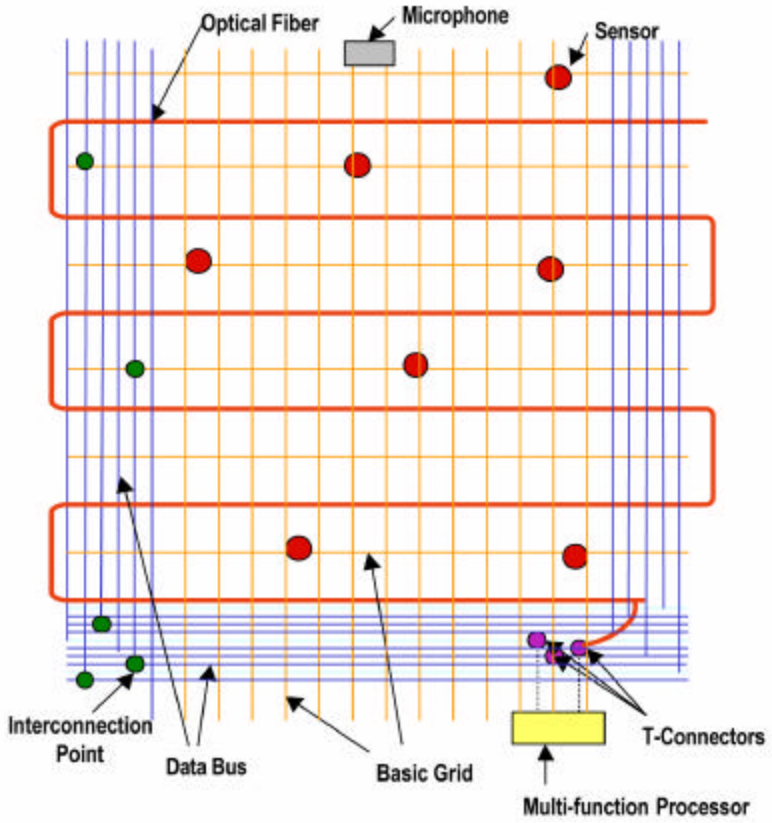






Electronic Preforms

- **Integrated Platform**
  - Electronic Textiles (E-Textile)
  - Concept of Fabric Motherboard
  - Large number of Active Devices
  - Smart systems (Integrated CPU)
  - Interconnects, System Integration
- **Growing Industry Base**
  - Wearable Computing
  - Medical, Fashion, Consumer Electronics
- **Use E-Textiles as Composite Preform**
  - Structure goes “LIVE”
  - Integration and Manufacturing Challenge



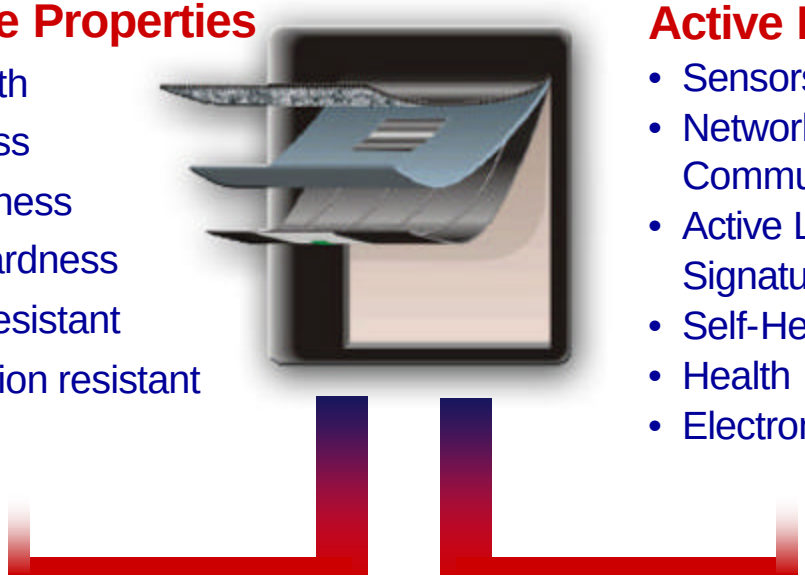
Multifunctional Composites Enable Transformation of the Navy

Combine Best of Both Worlds

New Initiatives

Passive Properties

- Strength
- Stiffness
- Toughness
- Fire-hardness
- Blast resistant
- Corrosion resistant
- LO



Active Properties

- Sensors/Actuators
- Networking and Communications
- Active LO and Signature
- Self-Healing
- Health Monitoring
- Electronics/CPU's

Manufacturing Technologies to Integrate Multifunctionality are Essential